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Mercury concentrations in bat guano from caves and bat houses in Florida and Georgia

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Running head: Hg in bat guano

**Abstract** Increasing concentrations of mercury in the environment from anthropogenic sources is a health threat for both humans and wildlife, and insectivorous bats are particularly vulnerable to this heavy metal via trophic transfer. A portion of the mercury bats ingest is excreted in their guano, which serves as a record of mercury contamination. Increased mercury levels are of particular concern in Florida, a state with high levels of mercury from local and global sources via atmospheric deposition. We measured total Mercury (THg) concentrations in bat guano from caves and bat houses in two cave regions in Florida and one in nearby Georgia to compare THg concentrations between cave regions and between caves and bat houses, which have different dominant bat species. Results show significant differences in concentrations between all three regions for guano in caves, but results were inconclusive for differences between concentrations of THg in bat guano between caves and bat houses. The mean concentration for all samples from all locations was estimated at 0.5410 +/- 0.0461 ppm, which is higher than concentrations found for ancient and historical guano in another study in the southeastern United States. This has implications for both the health of bats and cave ecosystems, as guano is an important food source for other cave species and could lead to increased Hg levels throughout the cave ecosystem.

**Keywords** Mercury, bat guano, bioaccumulation

**Introduction**

Increasing concentrations of mercury (Hg) in the environment from anthropogenic activity is a health threat for both humans and wildlife. Elemental mercury can transform in aquatic systems by bacterial methylation to methylmercury, a neurotoxin which bio accumulates in the aquatic and terrestrial food webs (Selin 2009). Methylmercury can then enter terrestrial food webs through consumption of fish or aquatic invertebrates. For example, Brasso and Cristol (2008) reported very high Hg concentrations in tree swallows (*Tachycienta bicolor*) which fed on insects that emerged from a Hg-polluted river in Virginia.

Due to several factors, insectivorous bats are particularly susceptible to Hg bio accumulation via trophic transfer through the food chain (Iskali and Zhang 2015). Bats take up Hg when feeding on large quantities of insects (e.g. mosquitoes) that accumulate Hg during their aquatic larval stages in Hg-contaminated waterbodies, as well as when feeding on terrestrial insects that bio accumulate Hg (e.g. spiders) (Brack and Whitaker 2001; Cristol et al. 2008). Bats have unquestionably been affected by this heavy metal, since several studies have found the presence of Hg in bat muscles, kidneys, livers, brains and fur (Miura et al. 1978; Powell 1983; Hickey et al. 2001; O’Shea et al. 2001; Yates et al. 2008; Wada et al. 2010; Yates et al. 2012). Heavy metal contamination has been linked to bat population decreases (Mickleburgh et al. 2002), and studies have shown sub lethal biological effects of impaired reproduction, chronic health issues and death in bats exposed to high contaminant loads of heavy metals (Clark and Shore 2001; Hickey et al. 2001).

One region in the United States where insectivorous bats are exposed to high levels of Hg in the environment is the southeastern U.S. coastal plain. This region includes the states of Florida and Georgia. In particular, Florida receives high levels of mercury from local and global sources via atmospheric deposition (Prestbo and Gay 2009). The Florida Atmospheric Mercury Study (FAMS) of air monitoring stations during 1994-1995 found that Florida had a yearly average of 900 pounds of mercury coming from rainfall (Stephenson 1997). The rainfall pollutes surface waters throughout the state and contributes to the trophic transfer of Hg from insects to bats. Once the bats ingest Hg, some of the metal is excreted in their feces (called guano), which primarily consists of bat hair, insect remains and bat mucus (Maher 2006). Over time, guano deposits in sheltered environments, such as caves, may accumulate vertically to sizeable depths and offer a chronostratigraphic record in a range of hundreds to thousands of years (Mizutani et al. 1992; Maher 2006). Florida and Georgia have several cave regions which provide habitat for several insectivorous bat species, and guano is found in many of these caves.

Few studies have focused on heavy metal concentrations in bat guano. Petit and Altenbach (1973) dated a guano core from a cave in Colorado and found levels of mercury throughout the core were related to production at a local copper smelter and open pit mine. O’Shea et al. (2001) found higher concentrations of environmental contaminants, including mercury, in bat guano near a superfund site than at a reference site in Colorado. Petit (1975) investigated mercury concentrations in a 1100 year-old guano core from an Arizona cave and suggested that Hg concentrations had been higher than expected in pre-industrial times, possibly due to geological processes such as volcanic activity. Clark et al. (1986) found elevated concentrations of the metals cadmium, chromium and zinc in guano from a cave in the Florida panhandle, but did not analyze for mercury. Cuculić et al. (2011) found bat guano was responsible for high concentrations of metals, particularly cadmium, in anchialine caves in Croatia (Hg was not analyzed). A recent study by Hagan (2014) analyzed three dated groups of bat guano from Mammoth Cave National Park in Kentucky and found that modern/fresh guano had higher concentrations of Hg than historical guano (~100-1100 years old), which in turn had higher concentrations than ancient guano (~30,000 years old).

For this study, we analyzed total mercury concentrations (THg) in bat guano from multiple caves in three cave regions and two bat houses, including one interstate overpass (I-75 in Florida), all within Florida and Georgia. We hypothesized that concentrations in guano from caves between regions would not be significantly different, since the same dominant bat species using these caves should have similar diets. But since the dominant species of bats differs between caves and bat houses, and these species have different diets, we hypothesized that concentrations between caves and bat houses in the same region could be significantly different. This data is valuable for monitoring potential mercury contamination in economically significant bat populations (Kasso and Balakrishnan 2013) and fragile cave ecosystems.

**Materials and Methods**

The guano from insectivorous bats in this study came from caves, bat houses and one interstate overpass (I-75) in Florida and caves in southwestern Georgia (Fig. 1). This guano was assumed fresh and deposited within the last few years, since caves in this region are prone to flooding, which likely transports guano after deposition and prevents long-term accumulation of guano piles. The effect of flooding on guano piles in regards to mercury mobility is also unknown, and stratigraphically dated guano piles provide inconsistent results (Zukal et al. 2015). Therefore, the guano cores in this study were subsampled to find spatial, but not temporal correlations of Hg.

Guano samples were taken from caves in two regions in Florida and one region in Georgia. To protect the bats and caves, numbers from the state cave surveys are used instead of cave names for sampling locations. Regions 1 and 3 are in Florida. Region 1 includes the caves Florida Cave Survey (FCS 2016) 229, 338, 440, 535, 537, 555, 556, 557, 565, 872 and 925. Region 3 includes the caves FCS 3, 84, 188, 213, 265, 1373, 1390, and 1630. Region 2 includes the caves from the Georgia Speleological Survey (GSS 2016) GGR 56, GSS 36, GSS 250, and two caves without survey numbers.

The dominant bat species roosting in Florida caves is the Southeastern myotis (*Myotis austroriparius –* MYAU) (Gore and Hovis 1998). The endangered Gray bat (*Myotis grisescens* – MYGR) was formerly abundant in some caves in region 1, but the Florida population has decreased in the last few decades and the species may no longer be present in the state (Gore et al. 2012). The caves in Georgia have MYAU and Tri-colored bats (*Perimyotis subflavus* - PESU) as the dominant species, as identified during bat surveys (pers. comm. K. Morris, Georgia Department of Natural Resources, April 24, 2013). MYAU forage largely over water bodies, and their diet preferences are predominantly mosquitoes, but also include moths, beetles, and other insects (FBC 2016a). PESU diets include mosquitoes and various insects such as moths, flies and beetles (FBC 2016b).

Two bat houses, one at University of Florida at Gainesville and one at the Lower Suwanee National Wildlife Reserve were sampled. The Brazilian free-tailed bat (*Tadarida braziliensis* – TABR) is the predominant species using bat houses and bridges in Florida (FBC 2016c), with MYAU also present. TABR diet preferences are moths, flies and beetles (FBC 2016c). Both bat houses are in Region 3 (Fig. 1).

Core guano samples in caves and bat houses were collected with a Russian sampler to avoid compaction of guano (Maher 2006, Johnston et al. 2010). Cores were divided into 1 inch subsamples starting from the top of the core. Sediment and guano from cave surfaces were collected with non-metal utensils in ~5 g amounts and put into plastic bags. All samples were stored in a freezer until freeze dried. All samples were collected between January 12, 2013 and February 13, 2014. All samples were freeze dried to constant weight, and analyzed for Total Mercury (THg) by thermal decomposition, gold amalgamation and atomic absorption spectroscopy (EPA method 7473) using a Milestone DMA80 mercury analyzer. This method was rapid and inexpensive, and provided detection limits in the sub-parts per billion range. QA/QC included blanks, replicates and matrix spikes. All duplicates had <10 percent difference and were averaged. The DMA80 was calibrated with NIST-traceable standards, and the calibration was verified using standards purchased from NIST and the National Research Council of Canada.

**Results**

All measured mercury concentrations in units of parts per million (ppm) are depicted in box plots in Figure 2. The leftmost (gray) boxplot shows all measurements (without respect to region), with the minimum observation at 0.0628 and the maximum at 2.1750. The mean concentration is estimated at 0.5410 +/- 0.0461 ppm. This boxplot shows three outlying points, which consist of measurements from two caves in region 1 (FCS 565 and FCS 556) and one cave in region 3 (FCS 188). These outliers may come from sampling bias from mercury “hotspots” in the guano piles. If they were removed from the analysis, the estimate of the mean concentration would be lowered to 0.5123 +/- 0.0316 ppm.

The three white boxplots in Figure 2 show mercury concentrations grouped by region. Of the three regions, region 2 typically has lower concentrations, with less variability than those in regions 1 and 3.

The samples in regions 1 and 2 came exclusively from caves, in which the typical species present are predominantly of species MYAU, PESU, and/or MYGR. Region 3 differs in that it includes guano samples from caves, bat houses, and an interstate overpass. While the caves in region 3 are populated by MYAU bats, similar to the caves in the other regions, the bat houses and the interstate overpass are predominantly populated by the TABR species.

Given the geographical differences among the regions, the data were examined for evidence of differences in mean mercury concentrations among the caves in regions 1, 2, and 3. Since no bat houses are present in regions 1 and 2, we limited this comparison to cave-based measurements.

The presence of the outlying observations and the different variability among the regions means that the traditional one-way analysis of variance is likely not appropriate here. Instead, we utilize an exact permutation test, which is a non-parametric statistical testing procedure. In addition, the structure of the data is nested; for example, measurements within each cave may be correlated, and are nested within cave and then within region. To accommodate potential correlational structure, we utilize an approach which considers all possible permutations of caves among regions, rather than individual measurements among regions (Anderson and ter Braak 2003). The resulting p-value is 0.0037, indicating a significant difference in mean mercury concentration in caves among regions 1-3. If our interests are limited to the surface measurements, we can conduct the same analysis, simply excluding measurements which were taken from the lower levels of guano core samples. In this case, the resulting p-value is 0.0173, in agreement with a finding of significant differences in the mean cave concentrations.

In region 3, three of the eight locations from which samples were drawn were manmade structures. These include 2 bat houses (at the University of Florida at Gainesville and Suwannee National Wildlife Refuge) and one interstate overpass (I-75 in Florida). The populations of bats inhabiting these areas are of different species than are found in the caves; they are predominantly of species TABR. For the purposes of this analysis, we group these structures together and, for simplification, refer to all three locations as “bat houses”. Figure 3 shows that in region 3, the mercury concentrations taken from the bat houses were generally somewhat lower than those taken from caves.

Another permutation test was used to investigate the question of whether the mercury concentrations differ between the bat house and cave-based populations in region 3.This test is considering all possible permutations of the 8 locations to the status of “cave” or “bat house”, comparing our actual results to those obtained with the various permutations. With no bat houses located outside region 3, we can only consider concentrations from the eight locations sampled in region 3. Even though we have 22 measurements in total, the permutation test accommodates the fact that the individual samples are nested within the sampling location (whether cave or bat house). This restriction limits the power of our testing procedure. The p-value for this test is 0.25, indicating that, based on this study, there is not enough evidence to indicate a significant difference in mean mercury concentration between bat house and cave populations in region 3.

**Discussion**

We hypothesized that concentrations in guano from caves between regions would not be significantly different, since the same dominant bat species using these caves should have similar diets. However, the resulting p-value for only cave guano, using both cores and only surface measurements, indicated a significant difference in mean mercury concentration in caves among regions 1-3. This could represent a mercury deposition “hotspot” in one region over the others. Greater atmospheric deposition of mercury in one region would increase bioaccumulation of mercury in the bat’s food supply, which could lead to greater bioaccumulation of mercury in the bats. Even among the measurements used in this study, we saw some outlying measurements from FCS 565, FCS 556, and FCS 188, with concentrations above 1.2 ppm. This may indicate that there are localized extreme hotspots within the regions we studied. While these measurements are difficult to obtain, investigation of this possibility would likely require more measurements in these localities.

We also hypothesized that since the dominant species of bats differs between caves and bat houses, and these species have different diets, that concentrations between caves and bat houses in the same region could be significantly different. The permutation test was inconclusive, but the concentrations from bat houses (dominant species TABR) were generally lower than the concentration in the caves (dominant species MYAU). This could be due to the different diets in these two dominant species, which would impact trophic transfer of mercury and subsequent bioaccumulation in the bats. MYAU diet is heavy on mosquitoes, which accumulate mercury during their aquatic larval stages in mercury-contaminated waterbodies. The other insects making up the dominant diet in TABR could possibly be less susceptible to mercury uptake than mosquitoes.

The estimated mean concentration of all bat guano in all three regions (caves and bat houses) is 0.5410 +/- 0.0461 ppm, and without outliers is 0.5123 +/- 0.0316 ppm. In comparison with the Mammoth Cave study (Hagan 2014), the guano from Florida and Georgia (both with and without outliers) is within the mean range of the modern/fresh guano (0.7 +/- 0.2 ppm) from Kentucky. This indicates that the modern/fresh guano from Florida and Georgia have similar Hg concentrations to the modern/fresh guano in Kentucky, with a cave in Florida having an outlier maximum observation of 2.1750 ppm. Kentucky is geographically not far from Florida and Georgia, and is likely experiencing the same phenomenon of increasing deposition and trophic transfer of Hg in the environment. Historical (~100-1000 years old) and ancient (~30,000 years old) guano from the Hagan (2014) study had lower than modern/fresh values of 0.20 +/- 0.05 ppm and 0.01 +/-0.0 ppm, respectively. The higher average concentrations in both the Kentucky and Florida bat guano indicates an increase in mercury bioaccumulation in bats in more recent history, although a different composition of bat species populations at Mammoth Cave could impact the comparison.

The concentration of mercury in bat guano has implications for both the health of bats and fragile cave ecosystems. Bats with white-nose syndrome have been found with elevated levels of contaminants and could potentially predispose bats to this disease (Kannan et al. 2010). The presence of Hg in guano affects not only the health of bats, but contaminated guano may allow Hg to bio accumulate in cave ecosystems and food webs for trogloxenes, troglophiles and troglobites. Coprophagy of guano has been observed in cave-adapted salamanders (Fenolio et al. 2006), dermestid cave beetles (Mizutani et al. 1992), and even meat ants who enter caves to collect and transport guano back outside to their mounds (Moulds 2006). Macroinvertebrate communities in caves have been found to increase after fresh guano is deposited (Poulson and Lavoie 2000), and the nutrient quality of guano has been found to influence biodiversity of macroinvertebrates in caves (Iskali and Zhang 2015).

Future studies could look at the methylmercury (MeHg) concentrations in both fresh guano and the hair from the bats roosting above the guano to correlate concentrations between the bats and the bat waste. It would also be beneficial to know if the bacteria that converts inorganic forms of mercury to methylmercury (MeHg) existed in caves, as the MeHg is the bioavailable form.

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**References**

ASTM Standard D2974. 2013. Standard test methods for moisture, ash and organic

matter of peat and organic soils. ASTM International, West Conshohocken, PA.

Anderson MJ, ter Braak CJF. 2003. Permutation tests for multi-factorial

analysis of variance. Journal of Statistical Computation and Simulation 73:85-113.

Brack V, Whitaker JO. 2001. Foods of the northern myotis, *Myotis septentrionalis*,

from Missouri and Indiana. Acta Chiropterologica 3:203-210.

Brasso RL, Cristol DA. 2008. Effects of mercury exposure on the reproductive success of

tree swallows (Tachycineta bicolor). Ecotoxicology 17:133-141.

Clark DR Jr, Wenner AS, Moore JF. 1986. Metal residues in bat colonies, Jackson

County, Florida, 1981-1983. Florida Field Naturalist 14:38-45.

Clark DR Jr, Shore RF. 2001. Chiroptera. Pp. 159-214 *in* Shore RF, Rattner BA, ed.

Ecotoxicology in wild mammals. John Wiley & Sons, New York.

Cristol DA, Brasso RL, Condon AM, Fovargue RE, Friedman, SL, Hallinger KK,

Monroe AP, White AE. 2008. The movement of aquatic mercury through terrestrial

food webs. Science 320:335.

Cuculić V, Cukrov N, Kwokal Ž, Mlakar M. 2011. Distribution of trace metals in

anchialine caves of Adriatic Sea, Croatia. Estuarine, Coastal and Shelf Science

95:253-263.

Edwards AE, Johnson E, Coor JL, Jagoe CH, Sachi-Kocher A, Kenney WF. 2016.

Historical record of atmospheric deposition of metals and δ15N in an ombrotrophic

karst sinkhole fen, South Carolina, USA. Journal of Cave and Karst Studies 78:85-

93.

FBC 2016a. Florida Bat Conservancy. <http://www.floridabats.org/Species_MYAU.htm>

Accessed October 13 2016.

FBC 2016b. Florida Bat Conservancy. <http://www.floridabats.org/Species_PISU.htm>

Accessed October 13 2016.

FBC 2016c. Florida Bat Conservancy. <http://www.floridabats.org/Species_TABR.htm>

Accessed October 13 2016.

Fenolio DB, Graening GO, Collier BA, Stout JF. 2006. Coprophagy in a cave-adapted

salamander; the importance of bat guano examined through nutritional and stable

isotope analyses. Proceedings of the Royal Society B 273:439-443.

FCS. 2016. Florida Cave Survey. <http://www.nssio.org/find_survey_overview.cfm>

GSS. 2016. Georgia Speleological Survey.

<http://www.nssio.org/find_survey_overview.cfm>

Gore JA, Lazure L, Ludlow ME. 2012. Decline in the winter population of gray bats

(*Myotis grisescens*) in Florida. Southeastern Naturalist 11:89-98.

Gore JA, Hovis JA. 1998. Status and conservation of southeastern myotis maternity

colonies in Florida caves. Florida Scientist 61:160‑169.

Hagan S. 2014. Mercury bioaccumulation in bat populations in Mammoth Cave National

Park: Modern, Historical, and Ancient Samples. Thesis. Western Kentucky

University. Kentucky.

Hettwer K, Deicke M, Ruppert H. 2003. Fens in karst sinkholes – archives for

long lasting ‘immission’ chronologies. Water, Air, and Soil Pollution 149:363-384.

Hickey MBC, Fenton MB, MacDonald KC, Soulliere C. 2001. Trace elements

in the fur of bats (*Chiroptera: Vespertilionidae*) from Ontario and Quebec. Canadian

Bulletin of Environmental Contamination and Toxicology 66:699-706.

Humphrey SR, Tuttle MD. 1978. Gray Bat. Pp 1-3 *in* Layne JN, ed. Rare and endangered

biota of Florida, Volume 1. University presses of Florida, Gainesville.

Iskali G, Zhang Y. 2015. Guano subsidy and the invertebrate community in Bracken

Cave: The World’s largest colony of bats. Journal of Cave and Karst Studies 77:28-

36.

Johnston VE, McDermott F, Tặmaş. 2010. A radiocarbon dated bat guano deposit from

N.W. Romania: Implications for the timing of the Little Ice Age and Medieval

Climate Anomaly. Palaeogeography, Palaeoclimatology, Palaeoecology 291:217-

227.

Kannan K, Yun SH, Rudd RJ, Behr M. 2010. High concentrations of persistent organic

pollutants including PCBs, DDT, PBDEs and PFOs in little brown bats with white-

nose syndrome in New York, USA. Chemosphere 80:613-618.

Kasso M, Balakrishnan M. 2013. Ecological and economic importance of bats (Order

*Chiroptera*). Biodiversity 2013.

Maher LJ Jr. 2006. Environmental information from guano palynology of insectivorous

bats of the central part of the United States of America. Palaeogeography,

Palaeoclimatology, Palaeoecology 237:19-31.

Mickleburgh SP, Hutson AM, Racey PA. 2002. A review of the global conservation

status of bats. Oryx 36:18-34.

Miura T, Koyama T, Nakamura I. 1978. Mercury content in museum and recent

specimens of chiroptera in Japan. Bulletin of Environmental Contamination and

Toxicology 20:696-701.

Mizutani H, McFarlane DA, Kabaya Y. 1992. Nitrogen and carbon isotope study of bat

guano core from Eagle Creek Cave, Arizona, U.S.A. Mass Spectroscopy 40:57-65.

Moulds T. 2006. The first Australian record of subterranean guano-collecting ants.

Helictite 39:3-4.

O’Shea TJ, Everette AL, Ellison LE. 2001. Cyclodiene Insecticide, DDE, DDT, Arsenic,

and mercury contamination of Big Brown Bats (*Eptesicus fuscus*) foraging at a

Colorado Superfund site. Archives of Environmental Contamination and Toxicology

40:112-120.

Petit MG. 1975. A Late Holocene chronology of atmospheric mercury. Environmental

Research 13:94-101.

Petit MG, Altenbach JS. 1973. A chronological record of environmental chemicals from

analysis of stratified vertebrate excretion deposited in a sheltered environment.

Environmental Research 6:339-343.

Poulson TL, Lavoie KH. 2000. The trophic basis of subsurface ecosystems. Pp. 231-249

*in* Wilkens H, Culver DC, Humphreys WF, ed. Ecosystems of the world, Volume 30:

subterranean ecosystems. Elsevier, Amsterdam.

Powell GVN. 1983. Industrial effluents as a source of mercury contamination in

terrestrial riparian vertebrates. Environmental Pollution 5:51-57.

Prestbo EM, Gay DA. 2009. Wet deposition of mercury in the US and Canada, 1996-

2005: Results and analysis of the NADP mercury deposition network (MDN).

Atmospheric Environment 43:4223-4233.

Selin NE. 2009. Global Biogeochemical Cycling of Mercury: A Review. Annual Review

of Environment and Resources 34:43-63.

Stephenson F. 1997. Florida’s Mercury Menace.

<http://rinr.fsu.edu/fallwinter97/features/mercury.html>. Accessed: April 23,2013.

Wada H, Yates DE, Evers DC, Taylor RJ, Hopkins WA. 2010. Tissue mercury

concentrations and adrenocortical responses of female big brown bats (*Eptesicus*

*fuscus*) near a contaminated river. Ecotoxicology 19:1277–1284.

Yates D*,* Moore M, Kunz T, Evers DC. 2008. Pilot assessment of methylmercury

availability to bats on the South River, Virginia. Report BRI 2008.

BioDiversity Research Institute, Gorham.

Yates D, Angelo S, Divoll T, Evers DC. 2012. Assessment of mercury exposure to bats

at Onondaga Lake, New York. Report BRI 2010-11. BioDiversity Research Institute,

Gorham.

Zukal J, Pikula J, Bandguchova H. 2015. Bats as bioindicators of heavy metal pollution:

history and prospect. Mammalian Biology 80:220-227.

Figure 1: Location Map

Figure 2: Measured mercury concentrations in ppm from all locations (left, gray box) and grouped by region (white boxes). Number of measurements shown in gray.

Figure 3: Mercury concentrations in ppm in samples taken from region 3, grouped by location type.





